8.0 ONBOARD INERT GAS GENERATING

The OBIGGS is a self-contained method of providing inert gas to the fuel tanks without relying on an airport to supply the inert gas.

The Onboard Inerting Designs Task Team reviewed the 1998 ARAC FTHWG report for inerting and determined that most of the nitrogen inerting technologies discussed in that report remained unchanged. The team chose to focus on air separator technology because of improvements in technology and manufacturing and the probable benefit of reduced cost.

The 1998 ARAC FTHWG found OBIGGS to be a heavy and expensive system. The FAA Tasking Statement for this ARAC has provided the means to reduce weight and cost, with specific recommendations to design without redundancy and to allow airplane operation when OBIGGS is inoperative. This has provided some improvements over the 1998 study.

Cryogenic distillation was investigated as a means to reduce the demands on the airplane. This technology produces nitrogen gas and stores liquid nitrogen by partially liquefying incoming air and separating the nitrogen. The nitrogen gas is used for on-demand inerting through all phases of flight. The liquid nitrogen is used to initialize and inert the fuel tanks at the start of the day. The cryogenic distillation system is not yet an available technology but is near term; that is, with current funding it could be available within 5 years.

8.1 SYSTEM REQUIREMENTS

The Tasking Statement requires that OBIGGS inert all fuel tanks during normal ground and typical flight operations. Nonnormal operations, such as an emergency descent, are not to be considered typical flight operations. This report will consider methods to minimize system cost, such as reliable designs with little or no redundancy, and recommendations made for dispatching in the event of a system failure or malfunction that prevents inerting one or more of the affected fuel tanks.

Secondary effects of the system must be described. The Tasking Statement requires that the FTIHWG analyze and report on extracted engine power, engine bleed air supply, maintenance impacts, airplane operational performance detriments, dispatch reliability, and so on. FTIHWG also is required to provide information and guidance for the analysis and testing that should be conducted to certify the system.

If the Working Group cannot recommend a system, the group is to identify all technical limitations and provide an estimate of the type of concept improvement required to make it practical in the future.

8.2 SYSTEM CONCEPT DESCRIPTION

Figure 8-1 shows the OBIGGS. In its simplest terms, the ASM pressurizes cabin air and separates it into nitrogen and other gases. This nitrogen is supplied to the fuel tanks while the other gases are exhausted overboard.

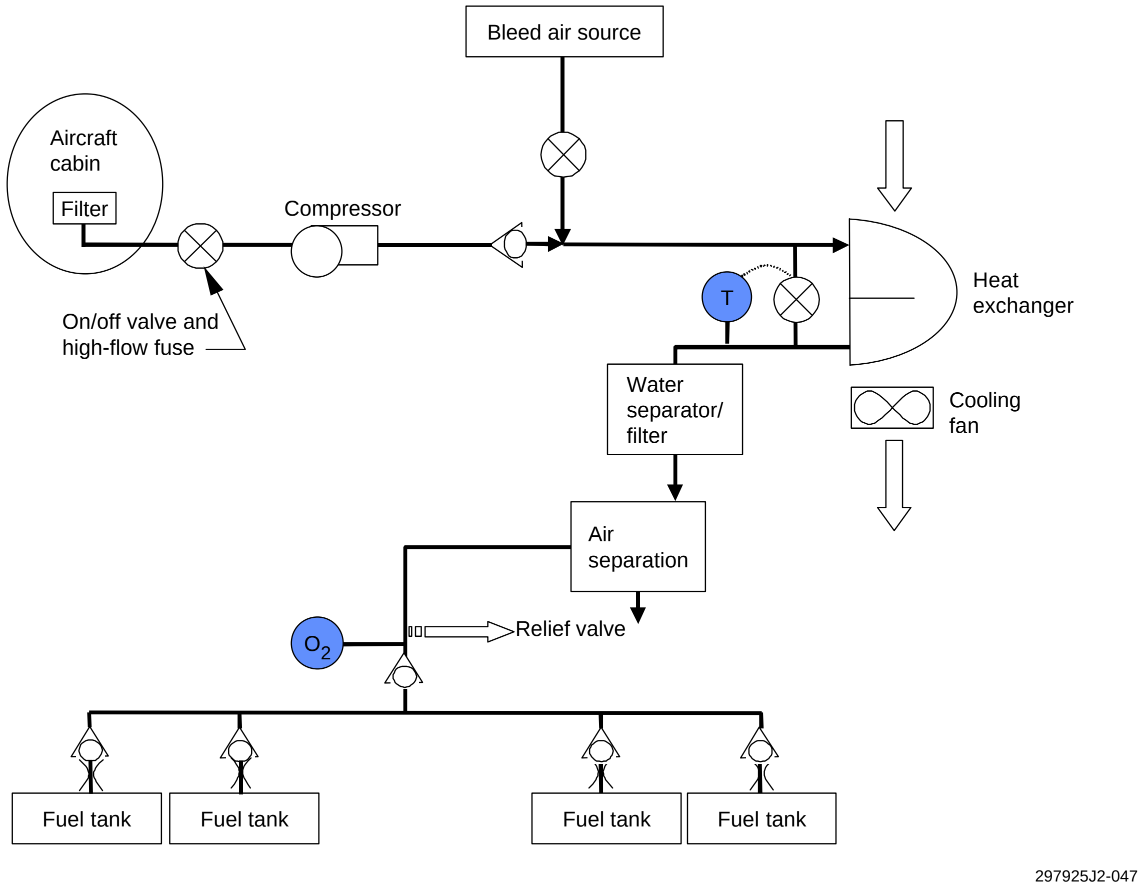


Figure 8-1. OBIGGS Schematic

The team reviewed and substantiated the 1998 ARAC FTHWG finding that engine bleed air is insufficient at critical times to supply OBIGGS. An electric compressor was deemed a viable primary source of air, when supplemented by engine bleed air as available.

The source air is cooled if necessary, water is removed to avoid icing, air is filtered to avoid ASM contamination, and the ASM separates nitrogen and supplies it to the fuel tanks.

The team hoped that using cabin air would reduce costs because it lowers the compressor's pressure ratio. ASMs require approximately 45 psia for their best performance. Ambient air at altitude is roughly 3 psia, requiring a compressor with a 15:1 pressure ratio. This is a daunting task. However, the cabin air is already pressurized to roughly 8 to 12 psia and is normally exhausted overboard, so this seemed a reasonable supply for the inerting system and only required a pressure ratio of between 4:1 and 6:1 from the compressor.

For passenger protection, a high-flow fuse closes to keep air inside the cabin in the event of a duct rupture in the inerting system. Similar valves are incorporated in airplane environmental systems today.

8.2.1 Air Source

The concept uses multiple air sources. Pressurized air can be provided by engine and APU bleed air or by the electric compressor. The air pressure supplied to the ASM is nominally 45 psia.

8.2.2 Pressure Ratio

The electric compressor was sized for a pressure ratio between 4:1 and 6:1. This provides 48 to 60 psia to the ASMs on the ground (depending on airport altitude) and about 44 psia in flight (depending on airplane altitude).

8.2.3 Air Separator

We studied three concepts for air separation. Hollow-fiber membranes separate nitrogen through molecule-sized passages when air passes through the length of the fiber. PSA adsorbs oxygen as air passes over the module, leaving nitrogen in the flowstream. Cryogenic distillation relies on separation of a partially liquefied airstream using a distillation column. The product is a high-purity nitrogen gas, which can be sent to the fuel tanks, or a high-purity nitrogen liquid, which can be stored for later use.

8.2.4 Descent Rate

Descent is the dominant airplane operation that determines the size of OBIGGS, and the faster the airplane descends, the larger the system required. OBIGGS prevents outside air from entering the fuel tank and increasing the oxygen concentration, so it must generate more gas during descent than at any other time in flight.

Military airplanes use climb-dive vent valves to keep outside air out of the fuel tanks, but these valves are quite complex because their failure could severely damage the fuel tanks. The FAA sought to avoid this complexity for the hybrid, and the Onboard Inerting Designs Task Team also wanted to avoid it for full-time OBIGGS. This goal requires that OBIGGS provide a high flow of nitrogen or high-purity nitrogen to dilute outside air as it enters the fuel tank (military systems with climb-dive vent valves can afford to provide slightly less flow). The team believes a somewhat larger OBIGGS was a lighter, cheaper choice than one using the complex vent valves.

8.2.5 Flammability Exposure

The flammability exposure is defined as the percentage of the airplane mission when the fuel ullage is flammable and not inert. The 1998 ARAC FTHWG found that CWTs had a flammability exposure of approximately 30%, and wing tanks had a flammability exposure of approximately 7%. The FAA has since been refining a model for flammability exposure, which was provided to this ARAC to compare system benefits. OBIGGS reduces the flammability exposure of all tanks to nearly zero.

8.3 APPLICABILITY OF CONCEPT TO STUDY-CATEGORY AIRPLANES

The design concept applies to all the airplanes in the study category. However, the high electrical demand may exceed the capacity of the existing airplane electrical systems and, at airports that discourage APU operation, the airport’s ability to provide the electricity.

An inerting system can be designed into future airplanes, provided the inerting system size is calculated before engine, APU, and electrical generator selection. This will ensure that bleed air or electrical power is available to supply the inerting system.

8.4 AIRPORT RESOURCES REQUIRED

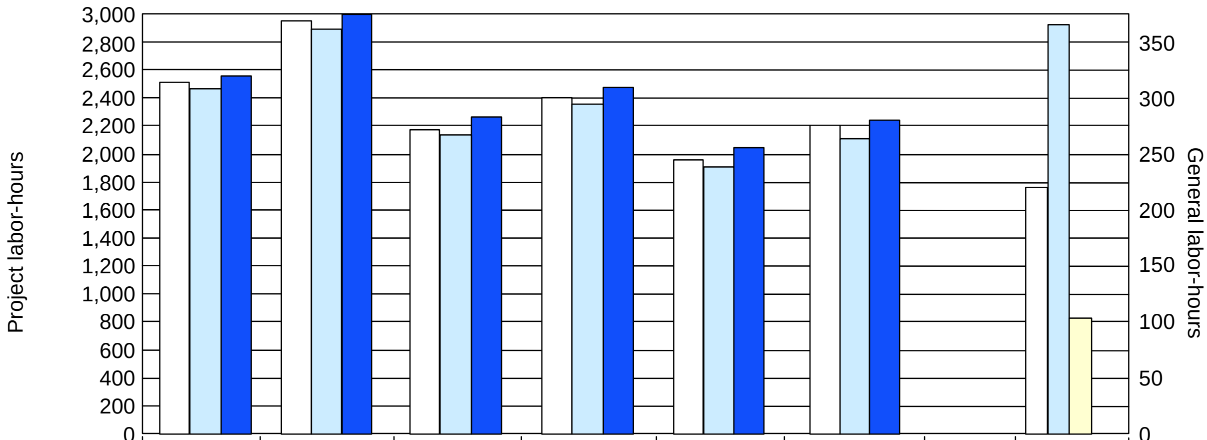
OBIGGS is a self-contained system that does not normally require any airport resources. However, ground electrical power may be preferred by some operators for systems without storage capabilities to power the system after tank maintenance and to inert the fuel tanks before the next flight.

8.5 AIRLINE OPERATIONS AND MAINTENANCE IMPACT

This section discusses the modification of in-service airplanes to install an OBIGGS and describes the overall effect of OBIGGS on airplane operations and maintenance requirements.

8.5.1 Modification

Figure 8-2 shows the modification estimates for the OBIGGS. Because there is insufficient space for the OBIGGS in the unpressurized areas of regional turbofan, regional turboprop, and business jet category airplanes, we have excluded these airplanes from this estimate. For the other airplane categories, estimates are made for both a regular heavy maintenance visit and a special visit. Appendix F, Airline Operations Task Team Final Report, addenda F.A.1 and F.A.2, contains a detailed table with costs and labor-hours.



Legend:	Large (heavy check)	Large (special visit)	Medium (heavy check)	Medium (special visit)	Small (heavy check)	Small (special visit)		General
Membrane	2,500	2,950	2,175	2,400	1,950	2,200		
PSA	2,450	2,900	2,125	2,350	1,900	2,150		
Cryogenic	2,550	3,000	2,275	2,475	2,050	2,250		
Engineering								220
Tech pubs								365
Material control								104
Training								
Flight ops eng								

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Figure 8-2. Modification Estimations for OBIGGS

After OBIGGS installation, an operational test flight may be required. The estimates do not account for costs of test flight.

8.5.2 Scheduled Maintenance

Scheduled Maintenance Tasks

The Scheduled Maintenance Subteam developed concepts for two types of OBIGGS and considered them separately. The subteam developed a list of scheduled maintenance tasks for a cryogenic OBIGGS and for a membrane OBIGGS using the system schematics provided by the Onboard Inerting Designs Task Team. The subteam evaluated each component illustrated in the schematic individually and wrote the tasks accordingly. These tasks included inspections, replacements, and operational and functional checks of the various system components. The subteam assigned these tasks to the various checks (A-, C-, 2C-, and heavy) and estimated labor-hours for each. Appendix F lists these tasks for each airplane category.

We assumed that tasks completed at a C-check would also be completed at a 2C-check. We made similar assumptions for the 2C-check tasks (i.e., they would be accomplished at the heavy check [or 4C-check equivalent]).

Both OBIGGS concepts consist of unique components that require additional tasks when compared with the GBI and OBGI systems. Thus, additional tasks are required, substantially increasing the extra labor-hours required in the C-, 2C-, and heavy checks.

Because of the size and complexity of the OBIGGS concept, we did not complete an analysis for turbofan, turboprop, and business jets category airplanes.

Pressure Check

Extra labor-hours have been added to each C- and heavy checks to perform a fuselage pressure decay check and rectification. The system uses cabin air as a supply for the inerting system, which increases the demand on the airplane air-conditioning packs. Consequently, the maximum allowable cabin leakage rate will have to be maintained at a lower level to ensure that the airplane air-conditioning packs will be able to maintain the required cabin pressurization.

Additional Maintenance Labor-Hours

Figure 8-3 shows the estimate for additional scheduled maintenance labor-hours required at each check to maintain a cryogenic OBIGGS. Figure 8-4 shows the estimate of additional scheduled maintenance labor-hours required at each check to maintain a membrane OBIGGS.

Airplane category	Additional A-check hours	Additional C-check hours	Additional 2C-check hours	Additional heavy check hours	Average additional labor-hours per year
Small	3	55	74	87	124.03
Medium	3	55	74	91	126.03
Large	3	55	74	95	115.52

Figure 8-3. OBIGGS Additional Scheduled Maintenance Times—Cryogenic System

Airplane category	Additional A-check hours	Additional C-check hours	Additional 2C-check hours	Additional heavy check hours	Average additional labor-hours per year
Small	3	50	65	76	113.96
Medium	3	50	65	80	114.56
Large	3	50	65	84	105.77

Figure 8-4. OBIGGS Additional Scheduled Maintenance Times—Membrane System

8.5.3 Unscheduled Maintenance

The full OBIGGS inerting system is the most complex system of all the design concepts studied. The characteristics that make OBIGGS different for other systems studied from a reliability and maintainability standpoint are its size and its operating time.

Because OBIGGS operates during all phases of flight it has an additional effect on other airplane systems. The demand the inerting system puts on the airplane electrical power generation, cabin pressurization, and engine bleed air systems will reduce the reliability and increase the maintenance requirements for these systems.

The larger size and weight of OBIGGS components will make performing maintenance more difficult and in some cases may create an additional safety risk when lifting the components during removal and installation.

System Annual Utilization Rate

The system annual utilization rate for OBBIGS, shown in figure 8-5, reflects the amount of time that any of the systems would operate in 1 year. We calculated this figure from the airplane daily utilization rate plus the minimum turn times, multiplied by the number of daily cycles. The large transport airplane with a high daily rate had the highest system annual utilization rate; the small transport came in a close second because of its high daily cycles.

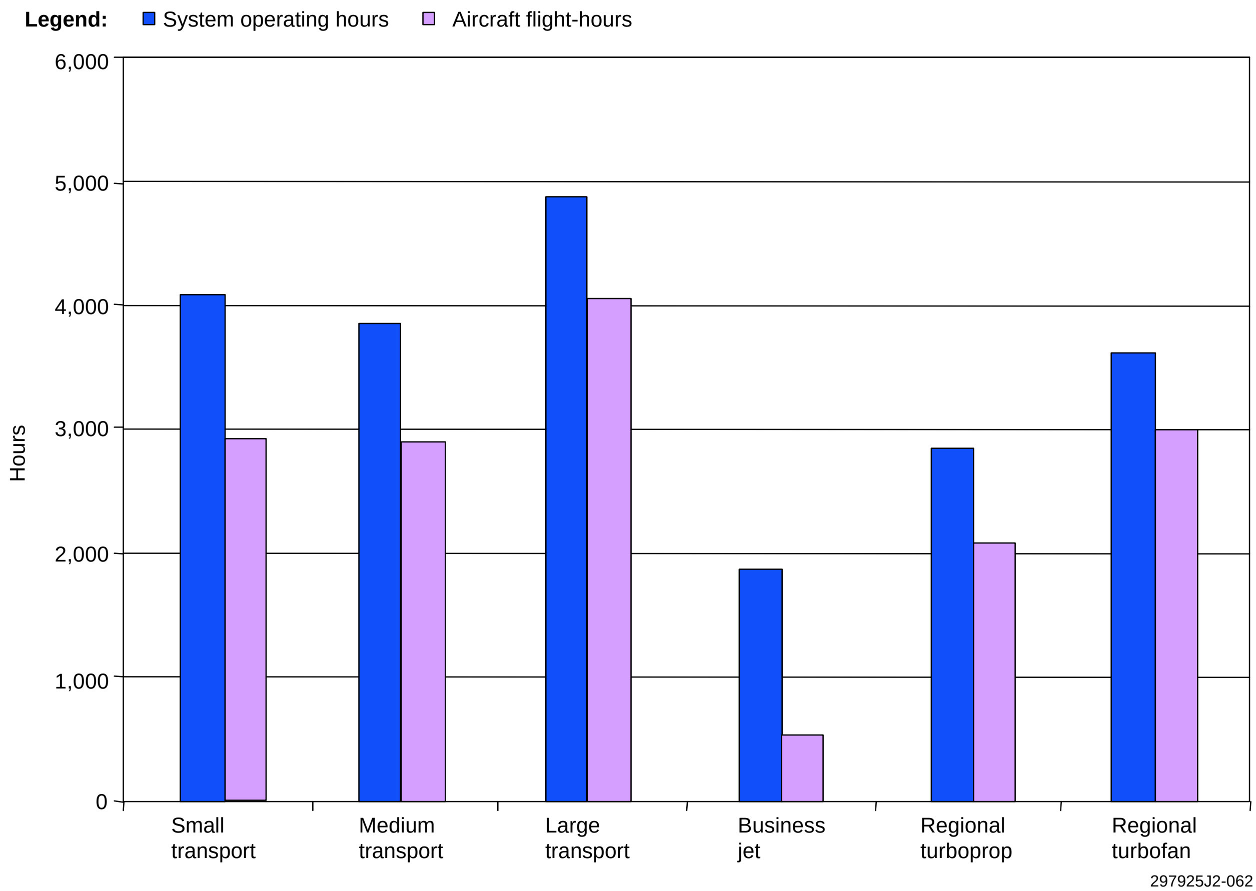

Figure 8-5. System Annual Utilization Rate

Component Reliability

To estimate the impact and related costs associated with the operation and maintenance of an OBIGGS we had to first establish a likely system reliability figure. From the system design we could compile a list of components for each system. In most cases it was possible to use historical data from similar components to suggest an OBIGGS component MTBUR. Where possible, more than one similar component was used.

One example of component reliability calculation was the OBIGGS shutoff valve. This valve would typically be a motorized butterfly-type valve that is found in many positions on different airplanes. Several similar valves were identified and, using the historical component MTBUR data from more than one operator, we calculated an average MTBUR figure. The OBIGGS design team suggested an MTBF of 50,000 hr; the average MTBUR figure was in fact calculated at 38,315 hr. This differential was expected and indeed confirmed that this method of MTBUR calculation was valid.

Where insufficient historical data was available, we used an MTBF figure, set by the system design team, or a most likely figure, based on team members' experience.

Establishing the component reliability in the form of an MTBUR figure was crucial in determining system reliability and in enabling the team to determine not only the component and system annual failure rate but overall impact on airplane maintenance and operations that result from system failures. This includes

- System weight.
- Cost to carry per airplane per year ($).
- System availability (driven by number of days of MMEL relief).
- Delays per year (hours).
- Delay costs per airplane per year ($).
- MMEL relief ranging from 0 to 120 days.

System Reliability

The MTBUR for the system was then determined from the individual component estimates.

We made an effort to determine the difference in MTBUR among airplane categories (fig. 8-6). Where sufficient component data was available, we found that there was little difference in MTBURs among the different airplane sizes. We felt that it did not prove to be a significant factor in further calculations. Therefore, with the resources available, we did not develop these figures further.

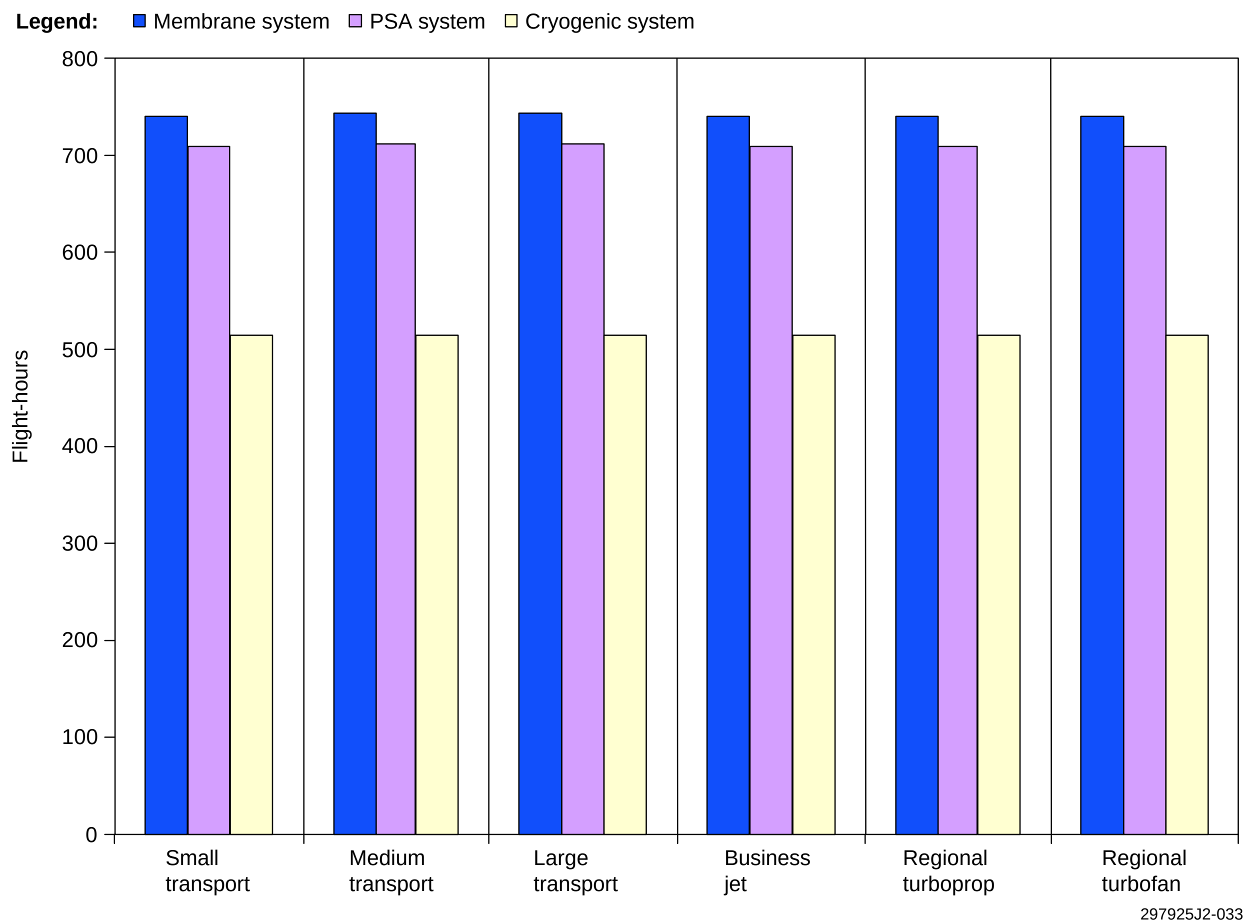

Figure 8-6. System MTBUR

System Annual Failure Rate

Using the component MTBURs and the airplane yearly utilization rate, we calculated the annual failure rate for each component. The system annual failure rate was the sum of these component annual failure rates.

As expected from the increased system complexity and the maturity of the cryogenic and PSA system technology, OBIGGS has a much higher predicted failure rate, shown in figure 8-7. This calculation was crucial for many further calculations such as system availability and the effects of different MMEL repair periods.

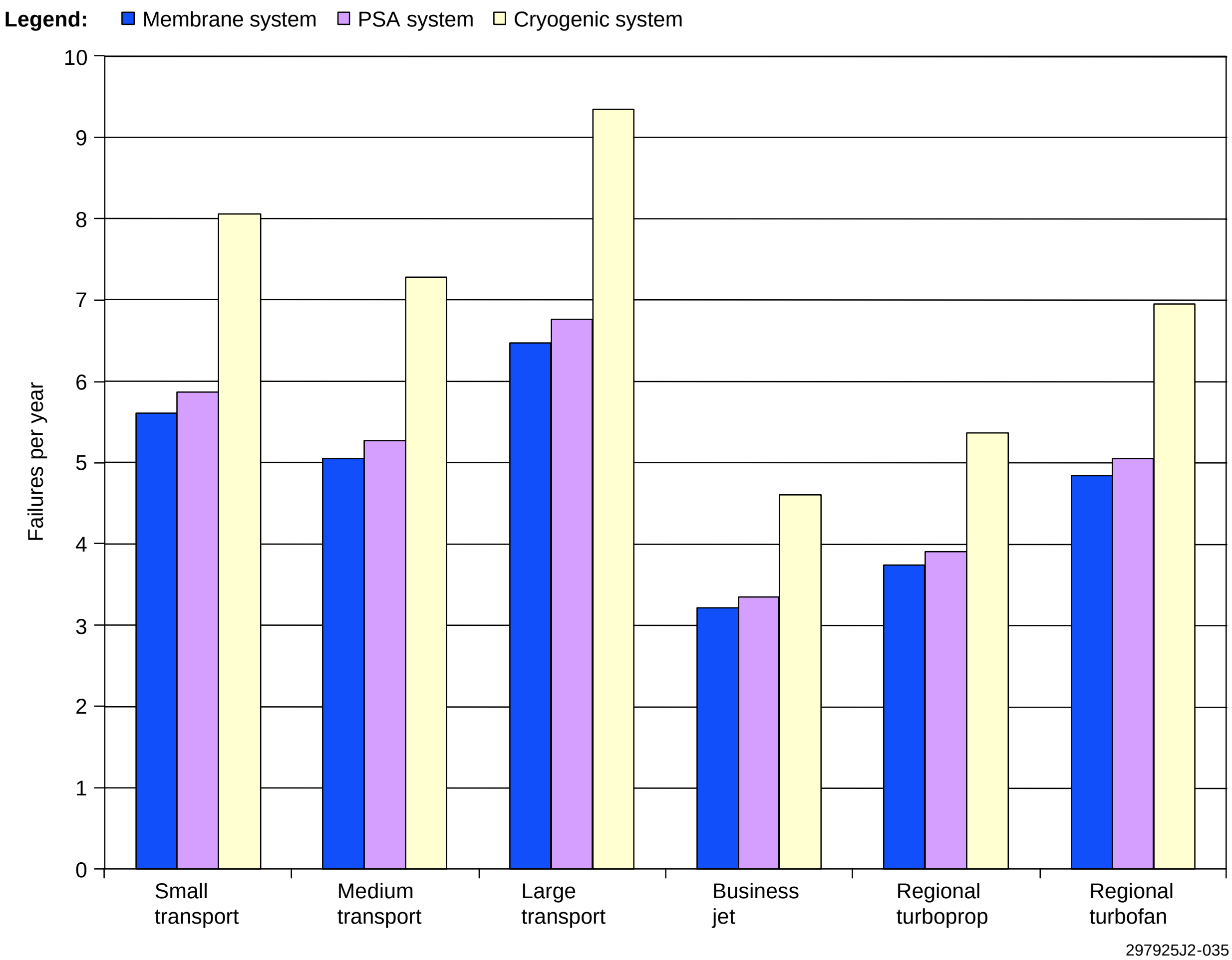

Figure 8-7. System Annual Failure Rate

Unscheduled Maintenance Labor Estimate

The amount of additional workload an OBIGGS would add to an airplane's maintenance requirements is a function of the annual failure rate and the component maintenance time, which in turn is a combination of the following:

- Component removal and replacement time.
- Component access time.
- Troubleshooting time.

To calculate the labor-hours per year we must make some assumptions as to the locations of the components. For example, the heaviest components would be located in areas that would allow access with lifting equipment (e.g., air-conditioning bay or wing-to-body fairing areas). We assessed each component individually and estimated the time to troubleshoot, access, and remove and replace based on similar tasks on existing airplanes.

The figures calculated refer only to the hours taken to rectify OBIGGS failures. It does not take into consideration the additional hours to maintain other airplane systems that are required to support OBIGGS (i.e., electrical or pneumatic systems) or systems affected by OBIGGS (i.e., cabin pressurization).

These figures may appear to be minimal but, where an operator has many airplanes arriving and departing within a short period of time, existing staffing levels may not be able to perform the rectification tasks, and additional staff will need to be recruited. This additional labor requirement is very difficult to quantify and has not been included. Therefore, the labor-hour estimate shown in figure 8-8 is presented as an indicator of the requirement for an increased number of maintenance technicians.

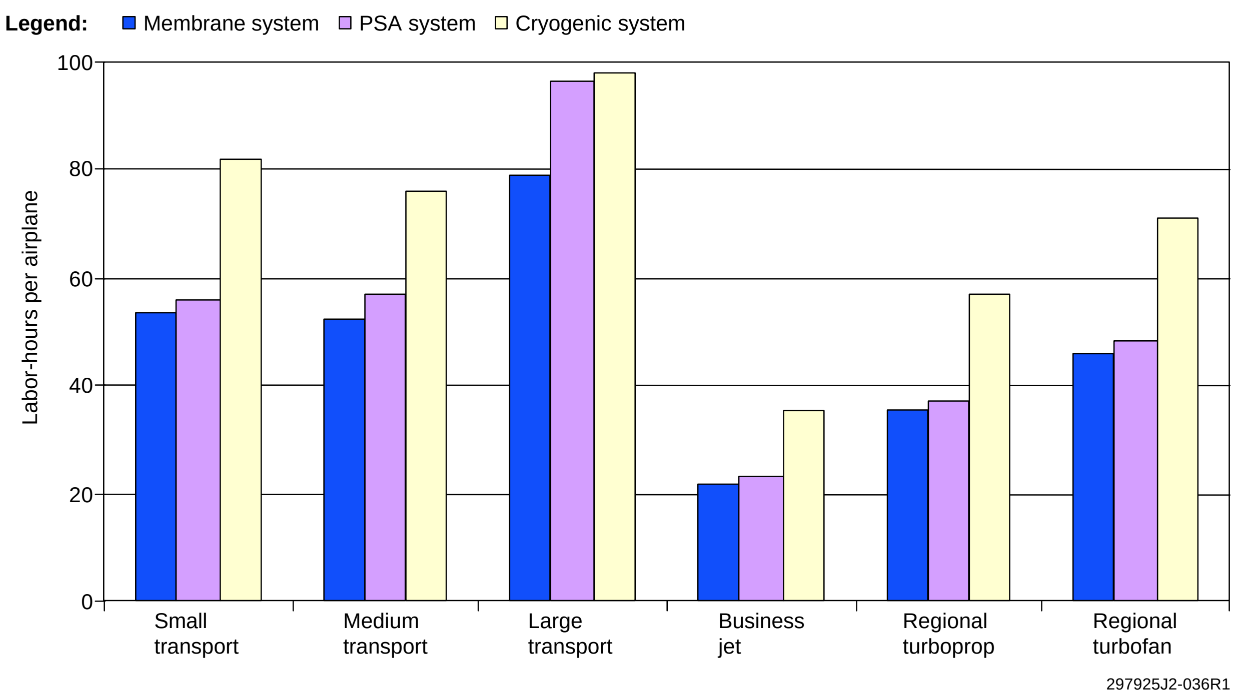

Figure 8-8. Additional Annual Labor-Hours

<u>*Annual Labor Costs*</u>

This is a product of the additional unscheduled labor-hours per year and the FAA's standard burdened labor rate for airplane maintenance technicians of $75/hr.

The costs shown in figure 8-9 are for the additional labor-hours only. Operators may have to hire additional staff to fulfil these requirements, resulting in an increased financial burden for recruitment, administration, and training of the required staff.

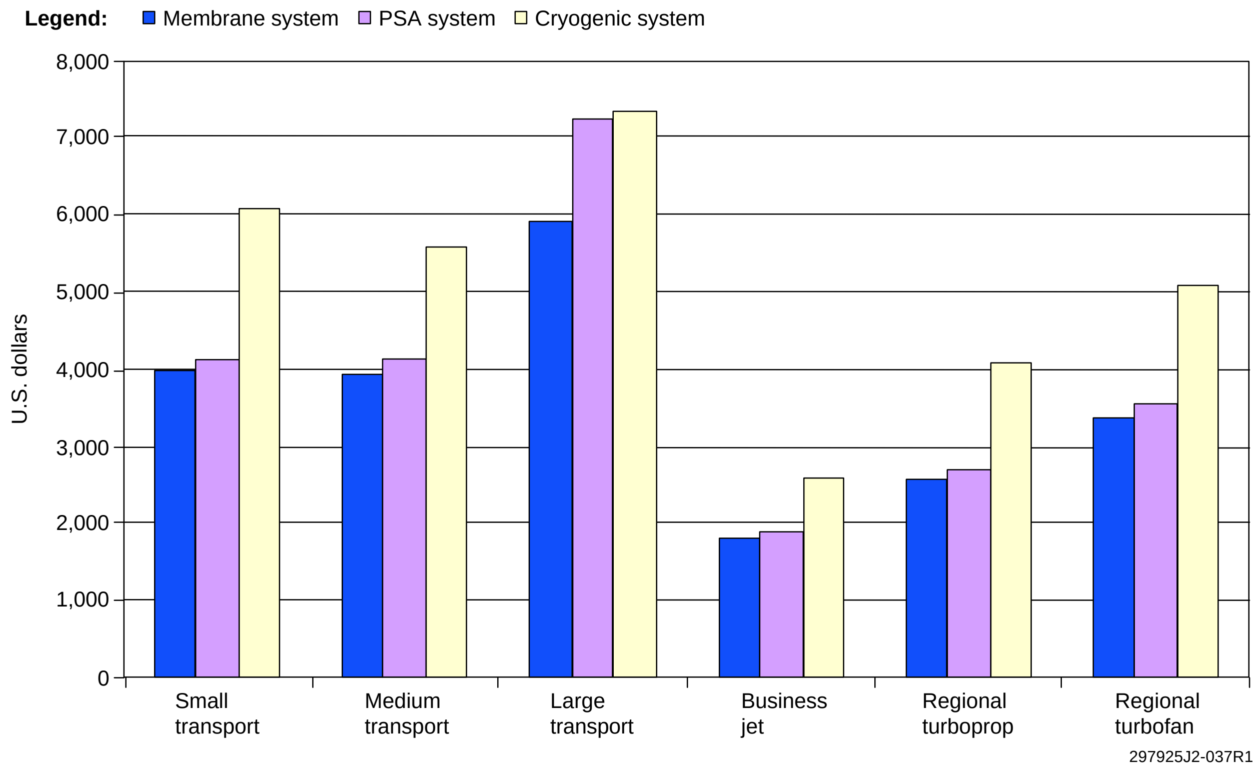

Figure 8-9. Additional Annual Labor Costs

System Weight

System weight has been calculated from the sum of the component weights specified by the design teams. The additional weight of the system installed on an airplane will not be limited only to the additional components. This estimate does not include the added weight of structural modifications to support heavy components.

Many operators are trying hard to reduce the weight of their airplane in an effort to achieve best economy.

This system weight has been used to calculate the cost to carry per airplane per year ($).

System Availability

System availability is a product of system annual failure rate and the variable input, MMEL repair interval. For example, if the system has a failure rate of five times per year and has 10 days' MMEL relief, the worst case scenario could mean that it is inoperative for 50 days per year, or 14% of the time. This would result in a system availability rate of 86%.

As mentioned earlier in this report, we evaluated the potential impact of 3-day and 10-day MEL repair intervals. Because system repairs are frequently accomplished in less time than the allowed per the MEL repair interval limits, we made assumptions on the average amount of time an inerting system would be inoperative under MEL relief. Under the 2-day MEL relief repair interval we assumed that the average system would be inoperative for 2 days. For the 10-day MEL relief repair interval the average system would be inoperative for 7 days.

The complexity of OBIGGS and the immaturity of both the PSA and cryogenic inerting technology result in a relatively high system annual failure rate, which drives the system availability rate down. Information from the Safety Analysis Task Team suggested that a system availability of 97.5% is desired to ensure the concept's predicted benefits. On most OBIGGSs, to achieve higher than 97% availability a 1-day MMEL repair interval is required but will seriously affect airline operations.

Figure 8-10 shows a comparison of the system availability of the membrane system with 1, 3, and 10 days' relief.

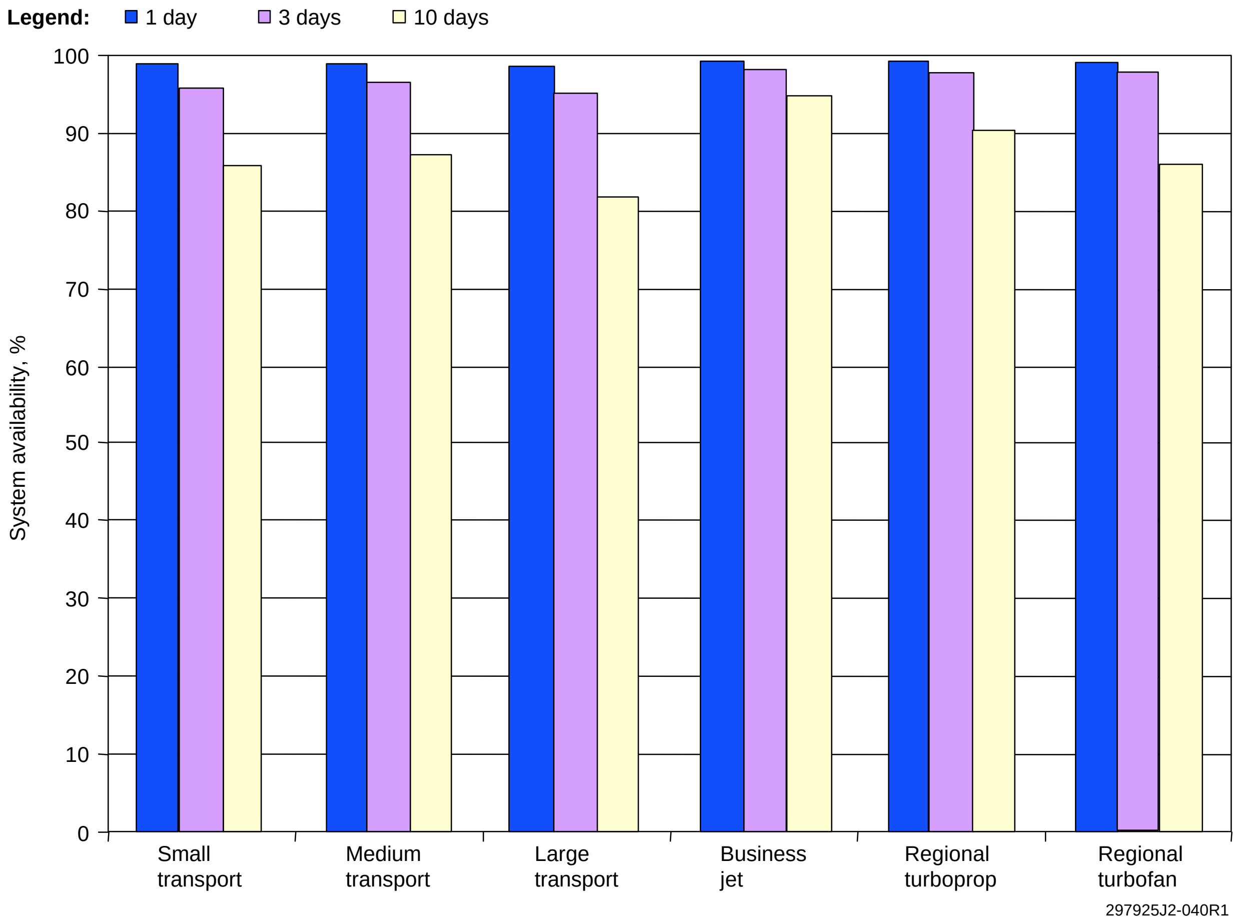

Figure 8-10. System Availability (10 Days' MMEL Relief)

<u>Delays per Year (Hours)</u>

We calculated the number of hours in annual delays, shown in figure 8-11, by making a delay assumption that if an airplane has a fault in the system it will take a period of time for the mechanics to assess the situation, perform any maintenance action in accordance with the MMEL, and complete any paperwork. Each airplane category has a delay assumption value that, when multiplied by the component annual failure rate, results in a total time delay for each component. The sum of the component delays results in the total annual system delay time (hours).

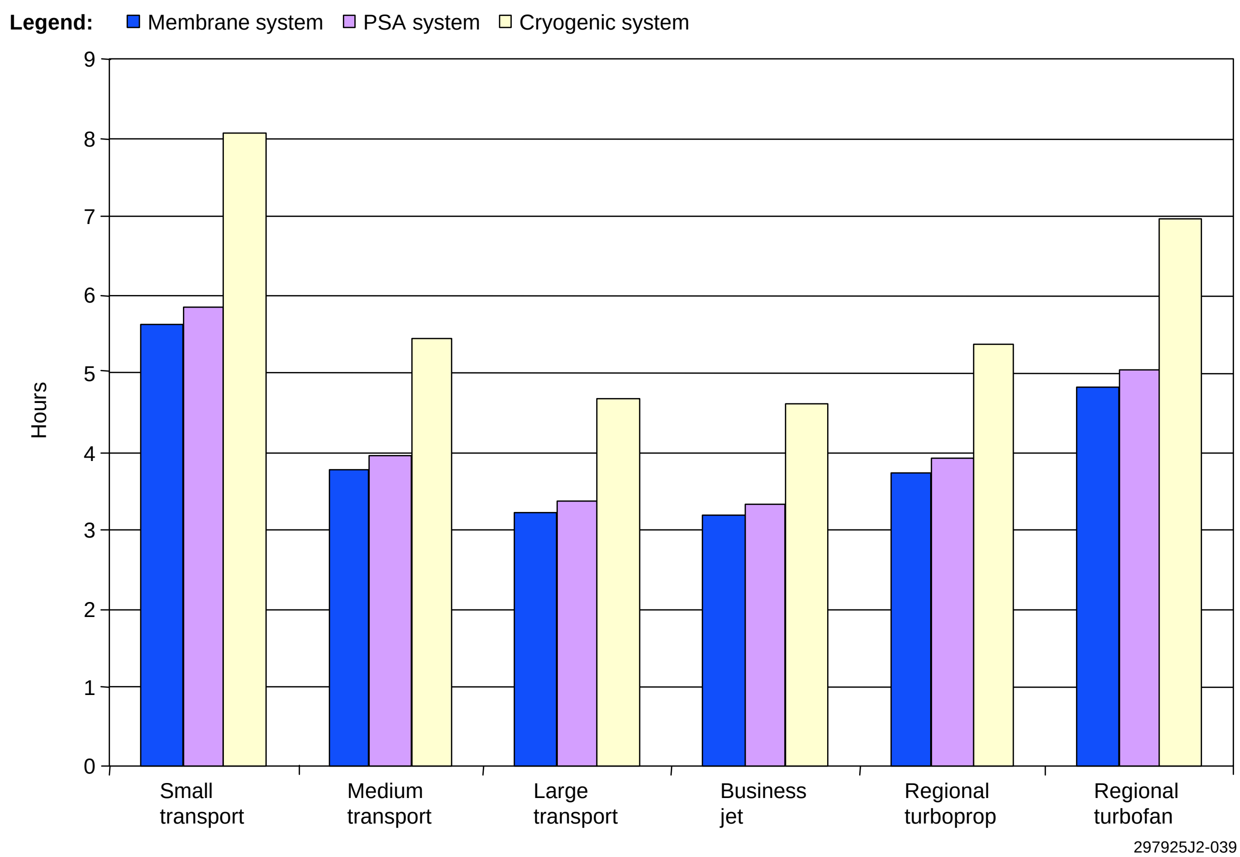

Figure 8-11. Delays per Year (Hours)

World reliability figures are measured against delays and cancellations. Customers are often driven by such figures, and operators make every effort to ensure on-time departures. Such delays and cancellations not only directly affect operators with costs of customer accommodation and remuneration but also loss of repeat customers and reputation.

The causes of such delays and cancellations are actively pursued by operators with a view to reducing them to the minimum, adding another system to the airplane that could affect such figures and is of great importance to operators.

Personnel Safety

It is a major concern for the operators and ground service agencies that installing an inerting system might threaten the safety of personnel. The danger to personnel from entering confined spaces that could be contaminated with NEA is a real possibility. In most developed countries health and safety legislation is adhered to much of the time, but in designing a system that reduces oxygen in some of the airplane's confined spaces, we could be building a trap for people to fall into.

Another major concern is the size and weight of some of the components in the various systems. These range from lightweight valves and other components to heavy compressors, heat exchangers, cryocoolers, and ASMs. These range in weight from 100 lb to more than 225 lb. There is a recognized need for specialized lifting equipment, but the risk of damage and injury from falling heavy components would exist where it previously did not.

<u>*OBIGGS Effects on Other Airplane Systems*</u>

The installation of an OBIGGS on an airplane will affect the reliability and cost of operation for other airplane systems. The OBIGGS concepts studied by this Working Group would add a very large additional electrical load on the airplane electrical system. The OBIGGS also relies on the airplane pneumatic system as a supplemental air supply, increasing the demand on this system. Last, in an attempt to reduce the size and power requirements of the OBIGGS air compressors, the design team chose to take the system's supply air from the passenger cabin. This will put an additional demand on the cabin air-conditioning and pressurization systems.

<u>*Electrical Power Generation*</u>

The OBIGGS power requirements may exceed the current available power.

For example, as shown in figure 8-12, the large transport airplane will require between 115 and 145 kVA. A typical Boeing 747 Classic will produce a maximum continuous rate of 216 kVA, of which 175 kVA is required in cruise, leaving a maximum of 41 kVA. A further consideration is that this remaining power would be distributed among four power-supply buses that cannot be permanently linked.

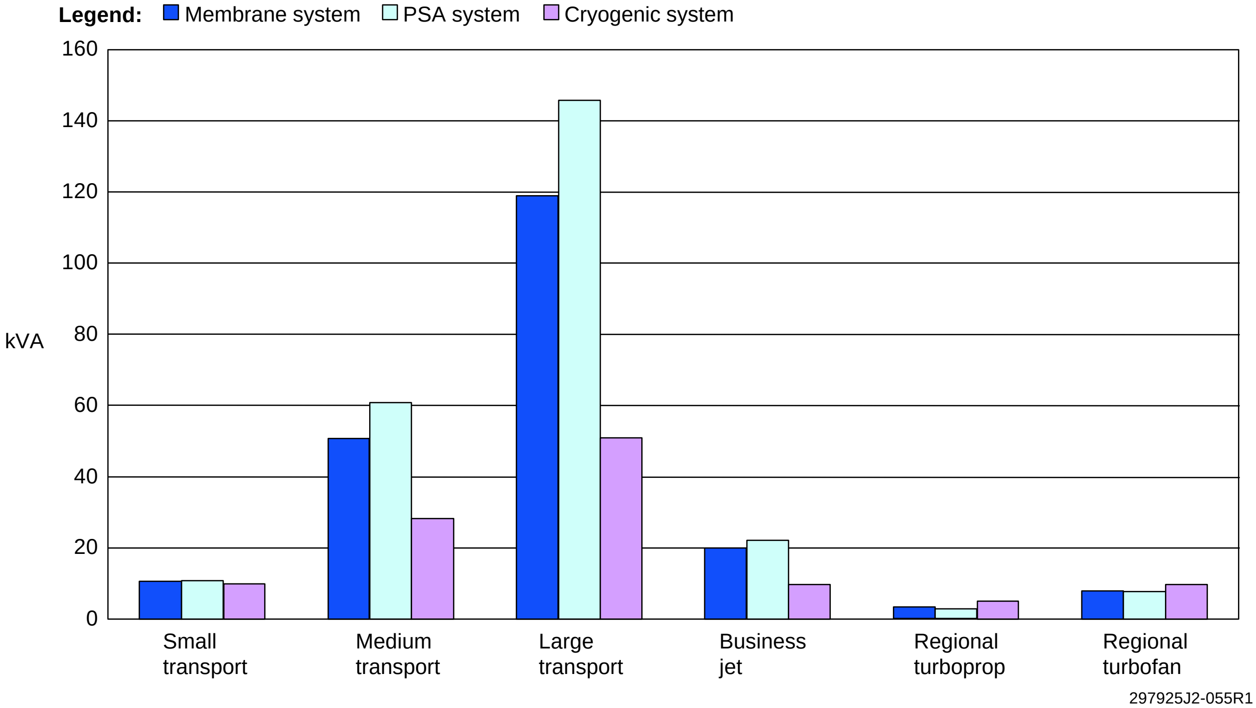

Figure 8-12. OBIGGS Power Requirements (kVA)

A Boeing 747-400 can produce more power because of greater capacity generators, but greater loads are required and the remaining power is again spread among power-supply buses that cannot be permanently linked.

Depending on the airplane, the increased power demands may require an increase to the capacity of the power-generating system. The cost of increasing the electrical system capacity and the cost of maintaining a larger system were not calculated. Increasing system capacity would require larger generators, heavier wiring, and modifications to the electrical buses to handle the loads. This may not even be an option on some airplanes because of engine limitations. Needless to say these changes would be expensive and time consuming.

Increased capacity power-generating systems will increase unscheduled maintenance requirements. This additional unscheduled maintenance figure has not been quantified, either.

Airplane Pressurization System

As previously discussed in the Scheduled Maintenance section, extra labor-hours have been added to the scheduled maintenance checks to perform a fuselage pressure decay check and accomplish repairs. Most operators' experience has shown that airplanes currently in service periodically require this pressure decay check to maintain leakage limits prescribed in airplane maintenance manuals.

Because OBIGGS takes air from the cabin, operators will have to reduce the allowable cabin air leakage rate to compensate for the demand and maintain a safety margin.

Should a leak occur during operation it may not allow continued operation of OBIGGS, which uses some cabin air pressure. Instead of allowing the airplane to continue in service until the next scheduled pressure decay check, immediate rectification will be required.

We have not quantified these extra unscheduled maintenance costs.

Bleed Air System

Bleed air also is used by OBIGGS. Where this system interfaces with OBIGGS, use and associated scheduled and unscheduled maintenance will be increased. Again, we have not quantified this increase in unscheduled maintenance.

Spare Parts Holding

The amount of spare components required to be held by an operator to ensure a reliable system varies according to system reliability, number of airplanes operated, and the type of operation, such as ETOPS. It was not possible to make a detailed study of the costs for all systems and airplane categories, but from the figures already calculated it was possible to see that a pool of spares of more than $900,000 would be required to operate one airplane with a membrane system. This figure is a conservative estimate and does not take into account the storage, transportation, administration, or capital investment costs or any lease fees.

8.5.4 Flight Operations

OBIGGS provides full-time inerting protection in normal operations including descent, landing, and postlanding incidents that might present a tank ignition hazard. The system should be designed to be fully automatic and to be automatically shed in case of engine power, electrical, bleed source, or cabin pressure failures. It is assumed that it will be monitored by the flight management systems and annunciation of failure modes will be provided to the flight crew for recording in the maintenance log. Little if any cockpit instrumentation should be provided because inerting is considered a safety enhancement with MEL provisions and the crew is not expected to troubleshoot it to reactivate the system or discontinue routing operations. Some basic descriptions of the inerting concept and the OBIGGS equipment, location, power sources, heat exchangers, and so forth need to be provided as additional training but should be limited to need to know. "If the crew cannot affect it, don't train for it." Both flight crew and dispatch personnel will be trained as far as MEL operating rules, and the airplane may need to be rerouted to a suitable repair facility. OBIGGS will draw power, bleed air, and incur drag from intercooler openings, and the increased fuel burn costs will result in reduced range and endurance. This could affect some long-haul and international routes.

8.5.5 Ground Operations

OBIGGS ideally would solve many of these ground-base concerns and issues after installation. The FTIHWG believes that a continual monitoring system should be installed on the flight deck to ensure that proper inerting takes place during the more critical phases of the airplane's route structure, such as taxi and takeoff. Any anomalies should immediately be put on a master caution light to alert the flight crew. The flight crew would then have the ability to shut the system down, if needed. Like the APU fire warning system on many commercial airplanes, an aural warning system should be considered while the airplane is on the ground in the event this system malfunctions without a flight crew member on board.

A valid concern was raised with the possibility of nitrogen entering the cabin during continuous inerting with this system. Considerations should be given to redundancy with the material used to enhance safety for passengers and crew. Examples include using double-walled pipe for plumbing purposes and installing nitrogen sensors in the cabin.

Maintenance training procedures fall within the above-mentioned training recommendations, and would merely be tailored again to the system desired for installation.

8.6 SAFETY ASSESSMENT

Figures 8-13 and 8-14 show the impact that OBIGGS could have on reducing future accidents in the United States and worldwide, respectively. If selected, the forecast assumes that the system would be fully implemented by the year 2015 (see sec. 11.0 for implementation assumptions). At that time, the forecast indicates the time between accidents in the United States would be 16 years with SFAR alone, 41 years with SFAR and inerting in heated CWTs, and more than 51 years for SFAR and inerting in all tanks. The corresponding time between accidents for the worldwide fleet would be approximately half that estimated for the U.S. fleet.

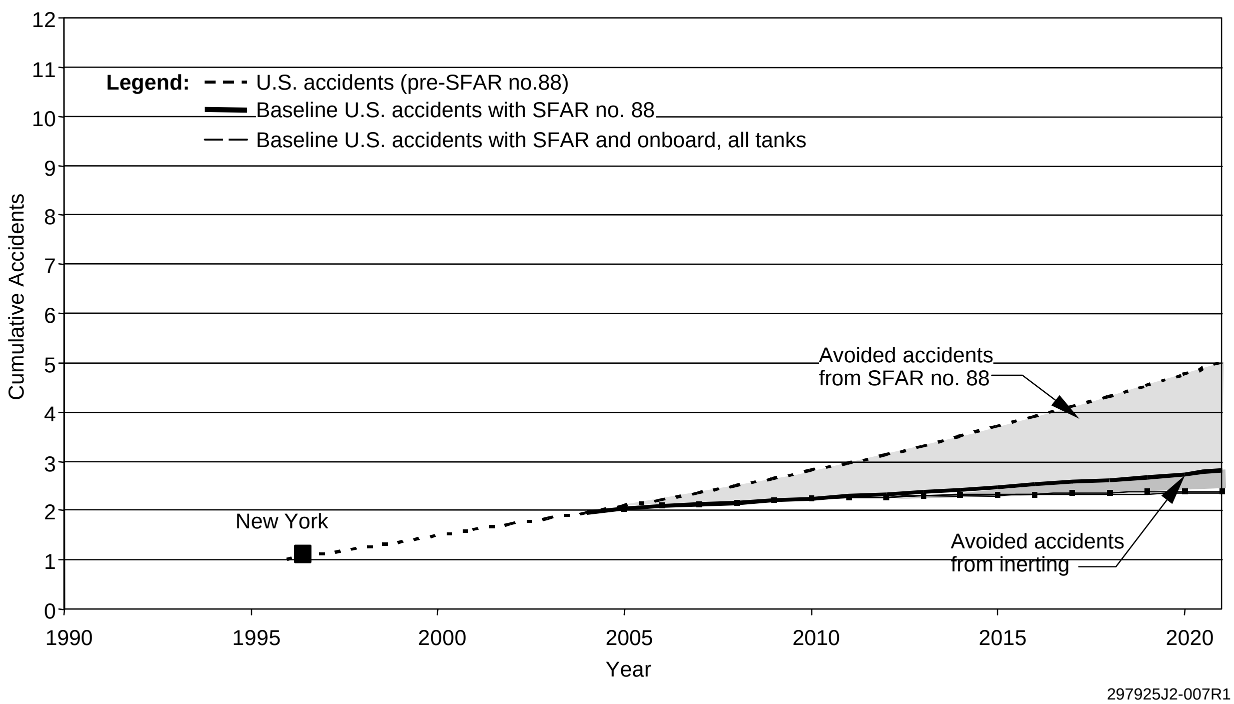

Figure 8-13. U.S. Cumulative Accidents With OBIGGS

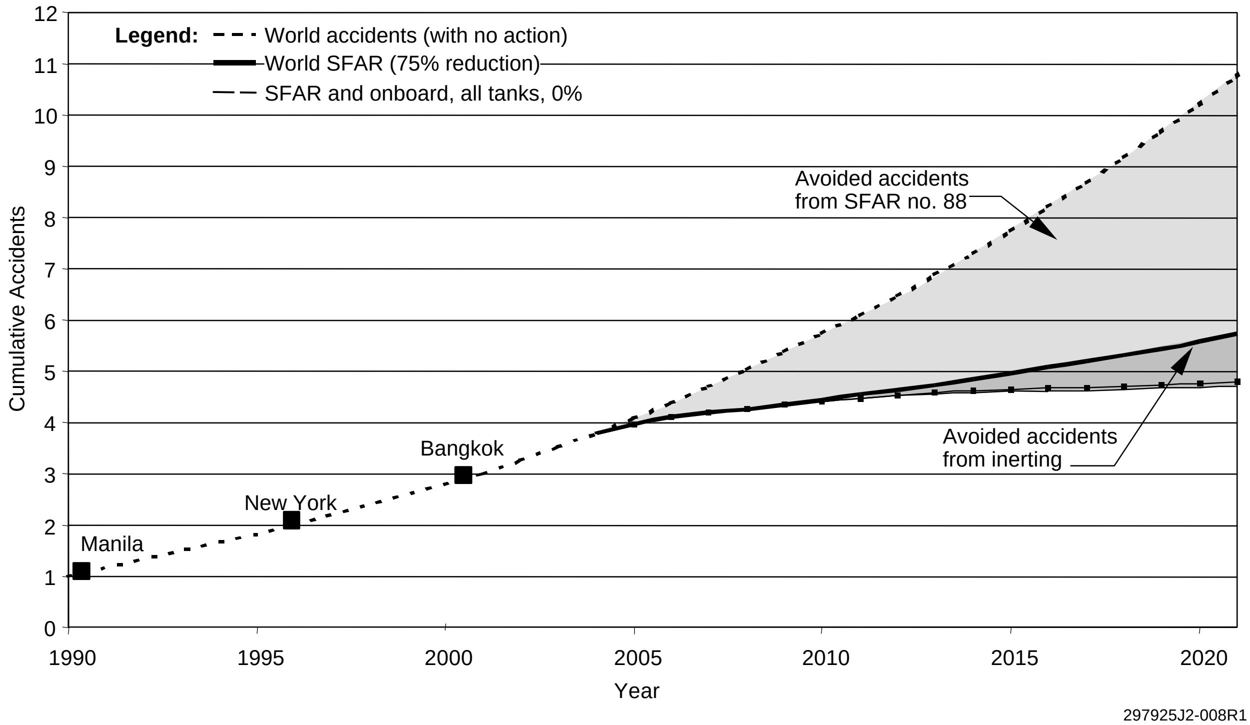

Figure 8-14. Worldwide Cumulative Accidents With OBIGGS

8.7 COST-BENEFIT ANALYSIS

Figures 8-15 though 8-21 graphically represent the cost-benefit analyses of the scenario combination examined for the OBIGGS concept.

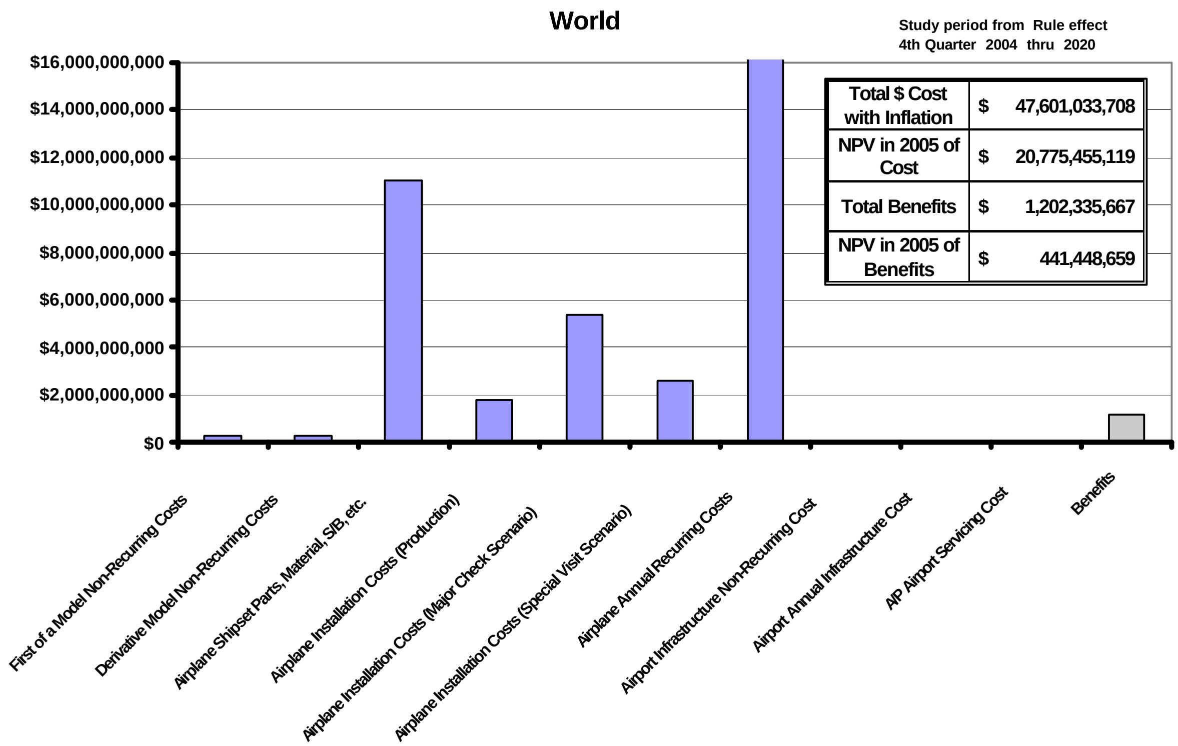

Figure 8-15. Scenario 5—OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems, and Small Transports, PSA/Membrane Systems (World)

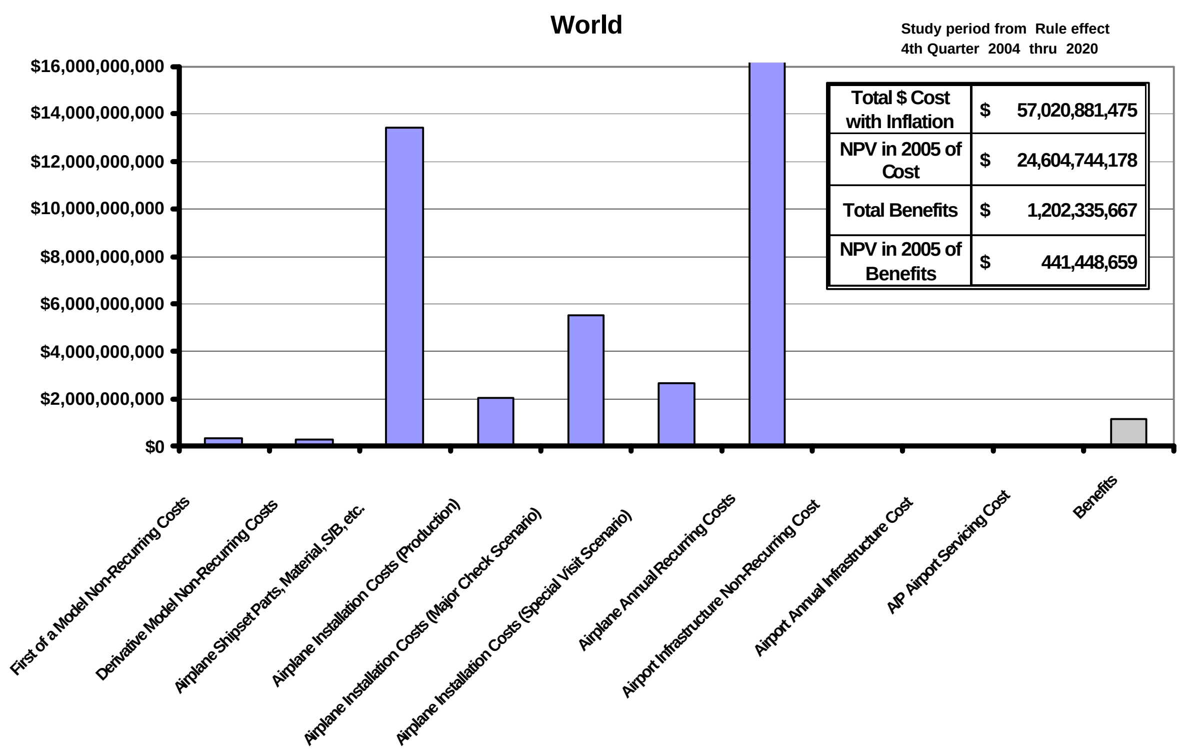

Figure 8-16. Scenario 13—OBIGGS, All Tanks, Large and Medium Transports, Cryogenic Systems, and Small Transports, PSA/Membrane Systems (World)

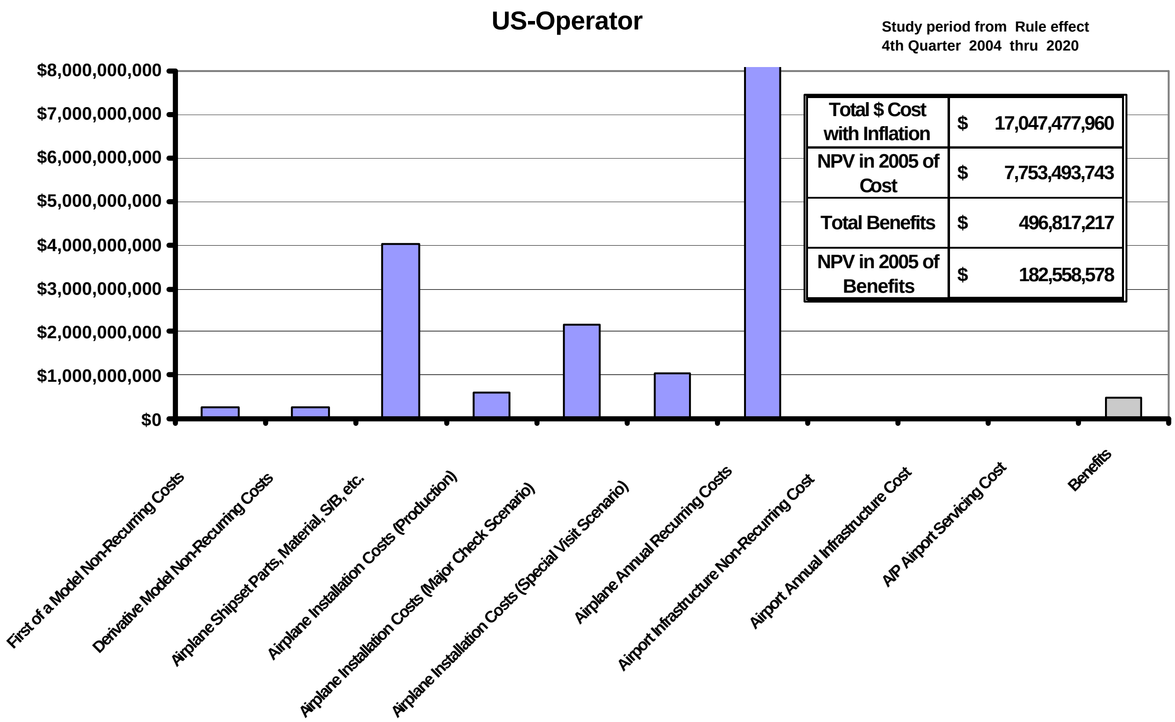

Figure 8-17. Scenario 5—OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems, and Small Transports, PSA/Membrane Systems (U.S.)

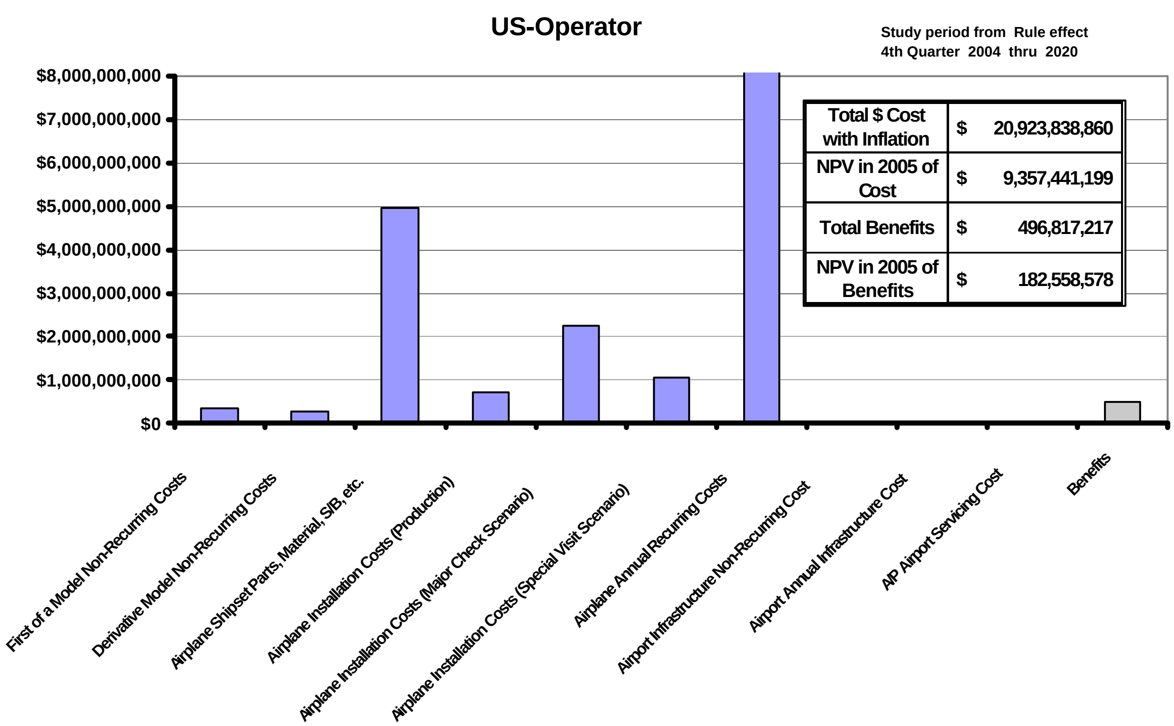

Figure 8-18. Scenario 13—OBIGGS, All Tanks, Large and Medium Transports, Cryogenic Systems, and Small Transports, PSA/Membrane Systems (U.S.)

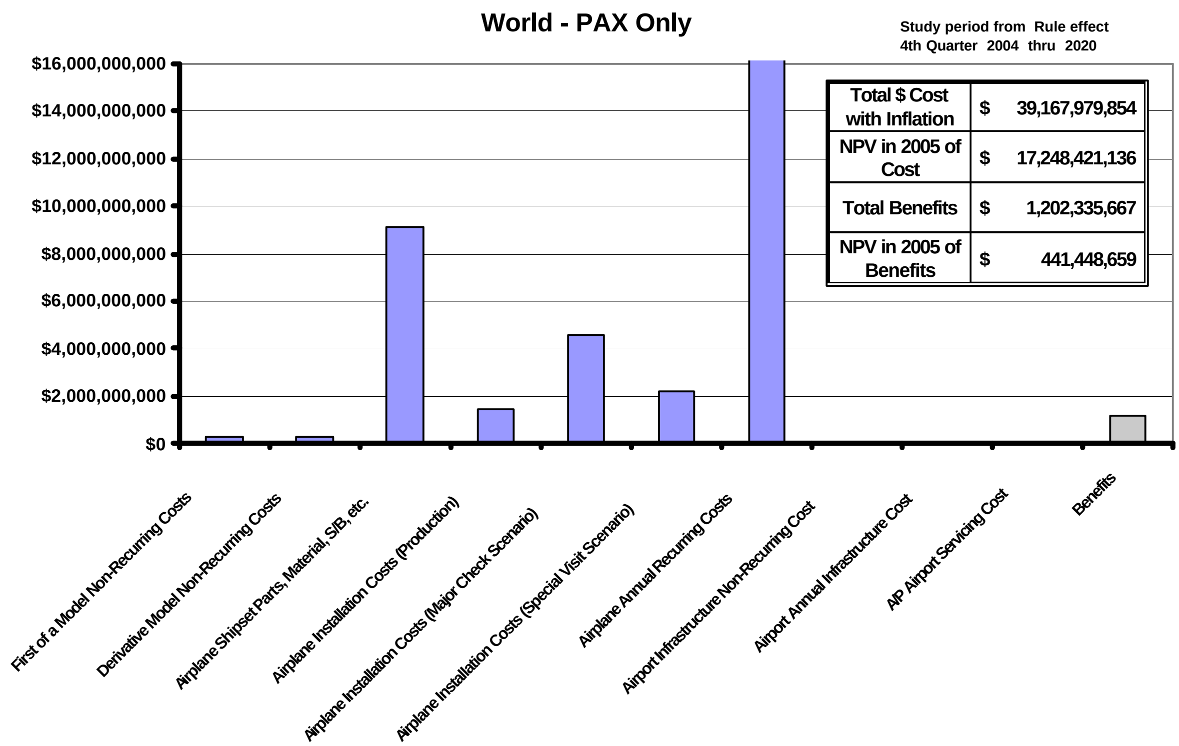

Figure 8-19. Scenario 5—OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems, and Small Transports, PSA/Membrane Systems (World, Passenger Only)

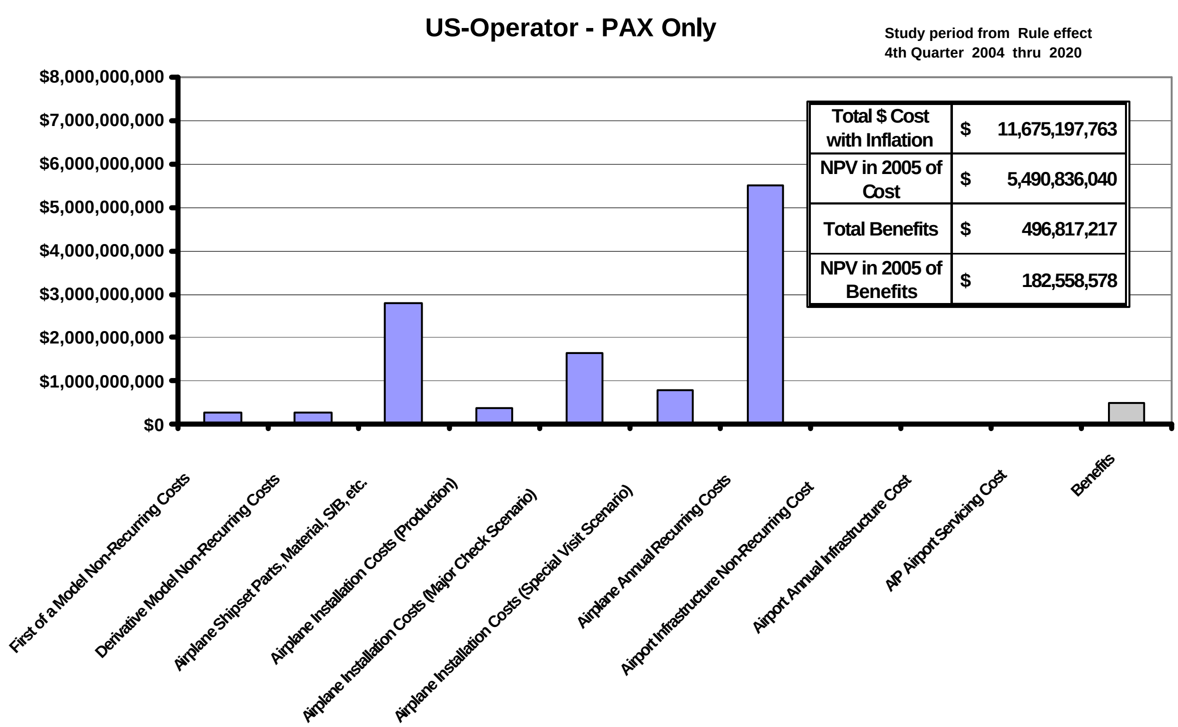

Figure 8-20. Scenario 5—OBIGGS, All Tanks, Large and Medium Transorts, Membrane Systems, and Small Transports, PSA/Membrane Systems (U.S., Passenger Only)

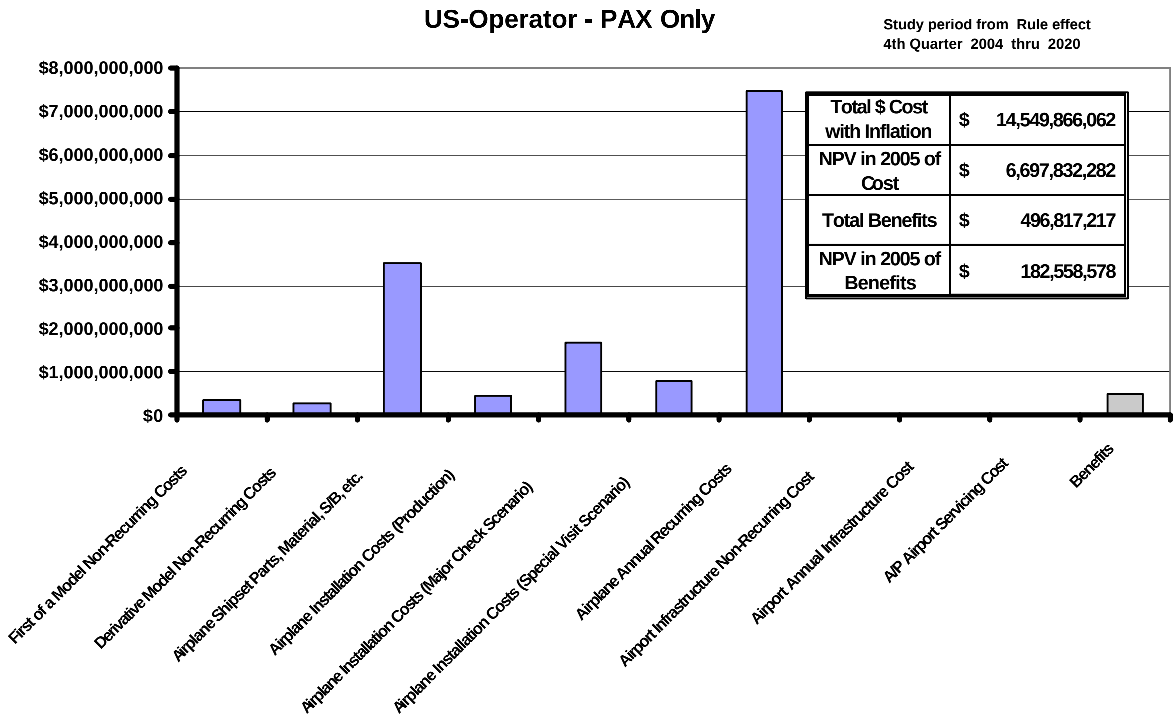

Figure 8-21. Scenario 13—OBIGGS, All Tanks, Large and Medium Transports, Cryogenic Systems, and Small Transports, PSA/Membrane Systems (U.S., Passenger Only)

8.8 PROS AND CONS

Pros

a. OBIGGS reduces total flammability exposure almost to zero, except for those times when the airplane is not powered or the maneuvers exceed typical maneuvering.
b. OBIGGS potentially reduces corrosion and condensation in the fuel tanks, depending on how the operator uses the system.

Cons

a. OBIGGS is the most costly option of those examined and weighs approximately the same as the OBGIS.
b. The cost of components (only a part of the total system cost) far exceeds the potential benefit.
c. Additional cost is incurred because of the weight of the system—which causes a fuel penalty—and airplane drag is increased, because of inlet and exhaust ports for the system.
d. The airplane's center of gravity may be adversely affected because of the system's location in some airplane models, which would also incur a fuel penalty.
e. Compressor and fan noise may have to be damped, depending on local noise standards.

Indeterminate

Pollution:

a. Normally, some fuel vapor exits the tanks during refueling and some vapor will be pushed out when adding nitrogen to the tank.

b. Fuel vent systems will need to be isolated to prevent crosswinds from diluting the nitrogen, which would be an improvement over present-day conditions.
c. No attempt was made to quantify this, because of the complexity of the problem for each airplane model at each airport.

8.9 MAJOR ISSUES AND RESOLUTIONS

The technical limitations for retrofit of the OBIGGS are its size, contamination issues with the ASMs, and a potential hazard with static electricity. A description of the improvements needed for the other limitations follows.

8.9.1 System Size

Some OBIGGS issues relate to the large system size, as shown in figure 8-22. For the large transport, the system weighs between 1,120 and 1,600 lb (depending on the separator technology) and consumes between 55 and 160 kVA of electrical power during descent. These power levels are a significant fraction of the large transport electrical capacity (240 kVA). The team was unable to obtain estimates of the electrical power available by flight phase to determine whether these power requirements could be met.

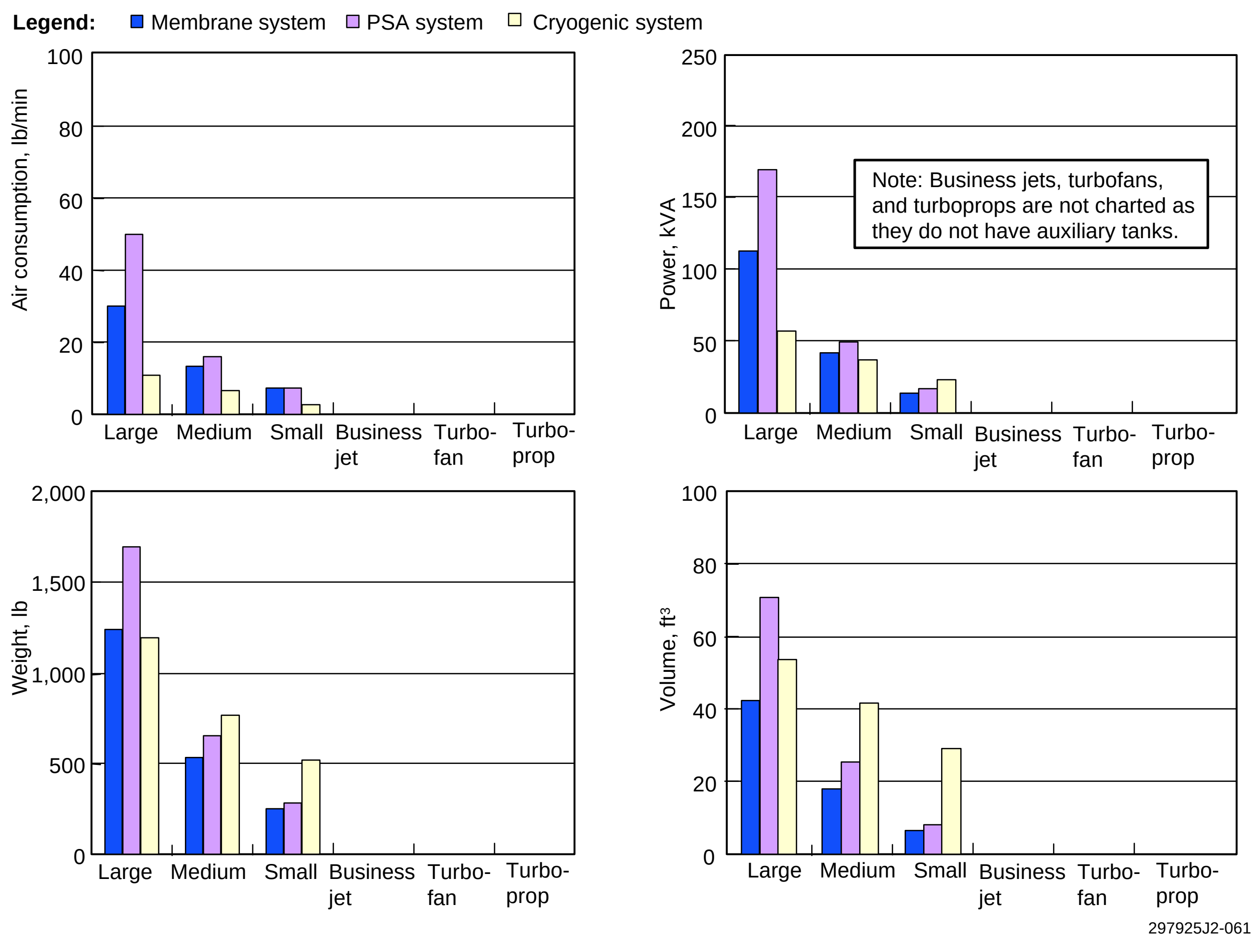

Figure 8-22. OBIGGS System Size Issues

No matter what size the airplane, the system requires significant electrical power to run, may not fit in all airplanes because of its size, and is heavy.

Another issue is the compressor weight, which for the large and medium transports is too much for an average mechanic to lift. This can be resolved by changing the design to incorporate multiple compressors in parallel, making each compressor smaller but increasing overall volume.

8.9.2 Air Separator Modules

ASMs are susceptible to water contamination, which reduces performance. A water separator has been included in the design concept to avoid this problem.

Some permeable membrane modules also are susceptible to hydrocarbon contamination from the fuel and oil vapor in engine bleed air. A hydrocarbon element may be required to be added to the coalescing filter included in the design concept.

In addition, permeable membranes have no service history onboard airplanes to prove their durability. They have been used in ground applications, however, where they have demonstrated a very long life.

Like permeable membranes, the cryogenic distillation system has no flight history. However, cryogenic distillation technology has been used for years on naval ships with high reliability.

8.9.3 Static Electricity

The rapid flow of dry gas in a distribution manifold inside the fuel tank can generate static electricity and cause sparks. This can be mitigated by using large-diameter manifolds to keep the gas velocity low and by bonding the manifold to structure (electrical ground).

8.10 CONCLUSIONS

OBIGGS reduces flammability exposure to nearly zero. But the concept suffers from keeping all fuel tanks inert during descent and from large ullage volumes required for short missions. The protection offered is the best a nonredundant system can offer, but at the highest price. Therefore, the FTIHWG does not recommend this concept.

9.0
Hybrid System